

# Hyperspectral remote sensing of crop properties with Unmanned Aerial Vehicles

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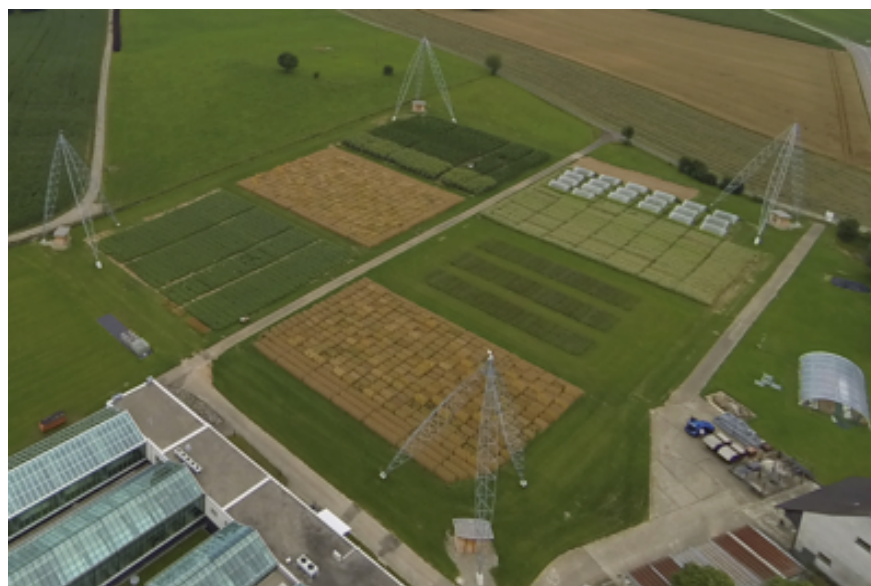
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Aerial hyperspectral remote sensing technologies provide effective methods for the exploration and study of the earth surface [1]. The recent progress in miniaturization of imaging and processing modules enables use of low-cost Unmanned Aerial Vehicles (UAV) as sensor carriers [2]. They offer a great potential for local area remote sensing applications, such as for agricultural, forestry, mining industry and hydrological applications. For agriculture in particular they will allow non-destructive detection of plant biophysical and chemical properties with a high spatial and temporal resolution relevant for precision farming and for agricultural research.

We present a case study conducted over the Field Phenotyping Platform (FIP) at the ETH Zürich research station for plant sciences at Eschikon, Lindau [3] depicted in Figure 1, as collaboration between EPFL TOPO laboratory, Gamaya company and the ETHZ Crop Science Laboratory. The aim of this case study was the determination of crop properties and phenotypes as related to spectral characteristics by using a novel Hyperspectral Imaging (HSI) snapshot camera developed by Gamaya [4].



**Figure 1. Field phenotyping platform (FIP) at the ETH Zürich research station for plant sciences at Eschikon, Lindau.**

Gamaya provides turnkey UAV-optimised hyperspectral imaging solutions for industrial applications. The developed cameras are capable of sensing up to 100 spectral bands in visible and near infrared spectra. In this study a model with 16 bands in the visible range was used. In particular, the snapshot imaging mode allows for the use of modern image processing-based techniques for the geometric registration of HSI data.

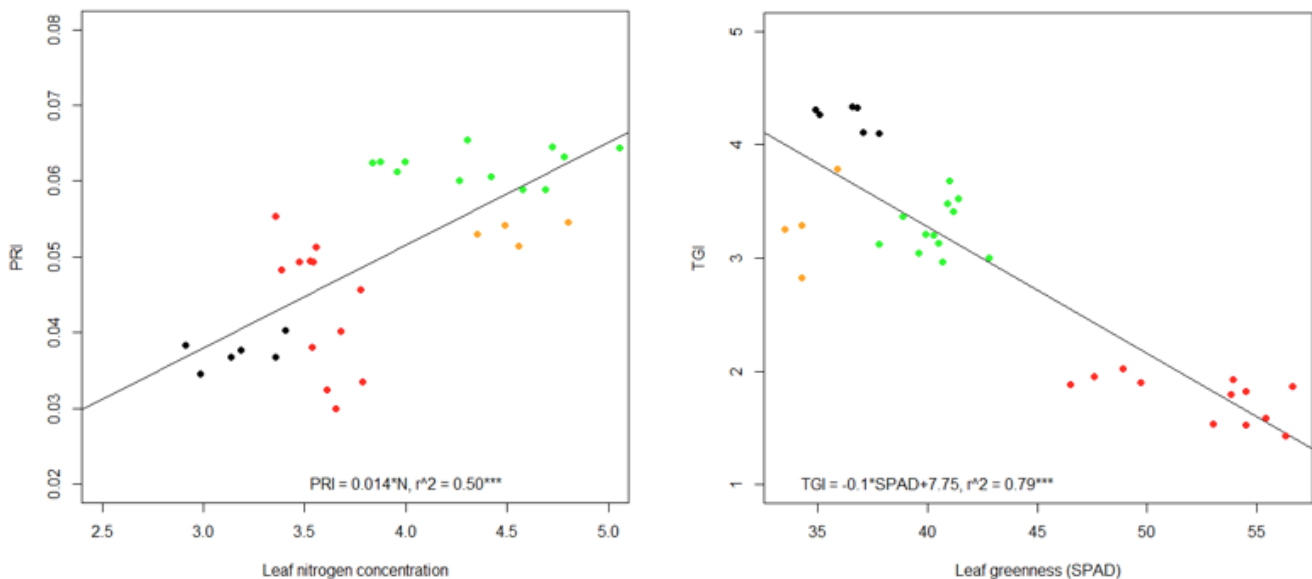
The UAV deployed during this study was a custom made hexacopter with Pixhawk autopilot [5] portrayed in Figure 2. The unit allows for execution of manual and automatic flights as well as a tight integration with the imaging system. The cameras were integrated together with an embedded computer assuring a proper triggering and synchronization of all the components. Moreover, the camera sensor head was accompanied by Global Navigation Satellite System and Inertial Navigation System (GNSS/INS) constituting a compact all-in-one remote sensing system. The navigation and imaging systems were synchronized to provide precise position and orientation information for each acquired image that in turn speeds up the processing. In addition, the precise knowledge of exterior orientation parameters allows creating seamless orthomosaics and multispectral maps without the need of establishing ground control points which significantly reduces the time and resources (Figure 2, right). Particularly, this approach is required over areas with homogeneous or dynamic terrain, for example crop fields or water surfaces.

We extracted the spectral data from a set of 34 plots (4 m<sup>2</sup>) including a range of different crops (soybean, sunflower, maize and buckwheat) where plant properties were determined. We calculated nine spectral indices reported for visible range. The spectral indices were related to leaf nitrogen, chlorophyll and total pigment concentration (in mg g<sup>-1</sup>), canopy cover (fraction of plant per area %), leaf area index (m<sup>2</sup> m<sup>-2</sup>) and spad (leaf greenness). For each of the mentioned traits good to very good relationships were identified and are reported in

this contribution as illustrated in Figure 3. Further we show the applicability of the camera and UAV setup for identification of phenotypic differences in winter wheat trial with more than 200 genotypes.



**Figure 2.** Airborne HSI platform based on a custom made hexacopter UAV (left) and the Principle Component Analysis (PCA)-based visualisation of the FIP area, which was used in the study (right).



**Figure 3:** Triangular greenness index (TGI) as related to leaf greenness and photochemical reflectance index (PRI) as related to leaf nitrogen content (mg g<sup>-1</sup>). Green = soy bean, red = maize, yellow = sunflower and black = buckwheat.

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